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Moult migration of emperor geese *Chen canagica* between Alaska and Russia

Jerry W. Hupp, Joel A. Schmutz, Craig R. Ely, Evgeny E. Syroechkovskiy, Jr., Alexander V. Kondratyev, William D. Eldridge and Elena Lappo

J. W. Hupp (correspondence), J. A. Schmutz, and C. R. Ely, U. S. Geological Survey, Alaska Science Center, 1011 E. Tudor Road, Anchorage, Alaska, USA 99503. E-mail: jerry_hupp@usgs.gov. – E. E. Syroechkovskiy, Jr., Institute of Ecology and Evolution, Russian Academy of Sciences, Leninskiy Prospect 33, Moscow, 119071, Russia. – A. V. Kondratyev, Biological Research Institute of St. Petersburg State University, Staryi Peterhof, Oranienbaumskoye sch – 2, St. Petersburg, Russia. – W. D. Eldridge, U. S. Fish and Wildlife Service, 1011 E. Tudor Road, Anchorage, AK 99503. – E. Lappo, Institute of Geography, Russian Academy of Sciences, Staromonetny pereulok, 29, Moscow, 109017, Russia.

We studied reproductive success and post-breeding movements of 32 adult female emperor geese *Chen canagica* that were marked with satellite radio transmitters on their nesting area on the Yukon-Kuskokwim Delta (YKD), Alaska 2000–2004. All 16 females that failed to successfully reproduce departed the YKD and moulted remiges either on the north coast of the Chukotka Peninsula, Russia (n = 15), or on St. Lawrence Island, Alaska (n = 1). Of 16 females that successfully nested, one migrated to Russia following hatch whereas the remainder stayed on the YKD. While moulting on the Chukotka Peninsula, emperor geese with satellite transmitters primarily used coastal lagoons west of Kolyuchin Bay. We observed 21,150 adult-plumaged emperor geese during aerial surveys in Chukotka in 2002. Most (95%) were in the same region used by geese that had been marked with satellite transmitters in Alaska. The number of emperor geese observed in Russia was comparable to our estimate of $\geq$20,000 adults that either do not nest or nest unsuccessfully each year on the YKD, suggesting that most nonproductive adults, or $\geq$28% of the adult population departs the YKD to moult elsewhere. The number of moult migrants may be substantially higher in years of poor reproductive success or if adult-plumaged birds that are not of breeding age also leave the YKD. Moult migration of emperor geese between Alaska and Russia is likely substantially greater than previously believed. Russian moulting habitats are important to the North American population of emperor geese and events that affect survival of geese in Russia could impact population trends on the YKD. Protection of coastal lagoons on the north coast of Chukotka is warranted.

Emperor geese *Chen canagica* occur in both Russia and Alaska (Petersen et al. 1994, Kear 2005). Information on movements of emperor geese between Asia and North America is important to understand population structure, identify important habitats on both continents, and to evaluate potential vectors for avian-borne pathogens. Most emperor geese nest on the Yukon-Kuskokwim Delta (YKD) in western Alaska, with much smaller numbers nesting on the Seward Peninsula of Alaska, St. Lawrence Island, Alaska and in eastern Russia (Petersen et al. 1994). Limited movement of emperor geese from Russian nesting areas to autumn staging areas in Alaska has been observed (Schmutz and Kondratyev 1995), and some geese that nest on the YKD winter on the Commander Islands, Russia (Petersen et al. 1994). However little is known regarding post-breeding movements of emperor geese from nesting areas on the YKD to possible moulting sites in Russia. In many species of arctic geese, nonbreeding birds or those that did not successfully nest may depart the nesting area to moult remiges elsewhere (Salomonsen 1968, Hohman et al. 1992). Moulting areas are often at high latitudes in remote regions where human disturbance is minimal, predation risk is low, and high quality forage provides nutrients for growth of new feathers (Owen and Ogilvie 1979, Derksen et al. 1982, Fox and Kahlert 2000). The magnitude of moult migrations can be substantial as $\geq$90% nonproductive geese, or upwards of 50% of a population may depart nesting grounds for moulting areas (Abraham 1980, Zicus 1981, Lawerence et al. 1998, Reed et al. 2003). Geese may reside on moulting areas for 4–6 weeks (Derksen et al. 1979) and exhibit strong annual fidelity when returning to those areas (Sterling and Dzubin 1967, Bollinger and Derksen 1996). Because human disturbance can disrupt foraging behaviors and displace geese from moulting habitats (Sterling and Dzubin 1967, Miller 1994, Miller et al. 1994), identification and protection of moulting areas are important aspects in the conservation of arctic geese (Derksen et al. 1982, Hohman et al. 1992). Protection of seasonal habitats used by emperor geese is especially important to help insure that the species recovers from a $>$50% population decline that occurred from 1964–1985 (Petersen et al. 1994, U.S. Fish and Wildlife Service 2005).

We deployed satellite transmitters on adult female emperor geese on the YKD to study their spring migration and prenesting interval (Hupp et al. 2006a). During that study we had the opportunity to assess reproductive status and post-breeding movements of marked females. We also conducted aerial surveys for moulting emperor geese in coastal areas of the Chukotka Peninsula, Russia. Here we report on the location of emperor goose moulting areas as determined by satellite telemetry and aerial surveys, and provide an estimate of the number of nonproductive emperor geese that migrate from Alaska.

Methods

Satellite telemetry

We captured flightless adult emperor geese and their broods on the Kashunuk and Manokinak rivers of the YKD in July and August 1999, 2002, and 2003 (Fig. 1). We selected adult females that showed evidence of a brood patch and transported them from capture sites to nearby field surgical facilities where veterinarians implanted a 45 g (1999) or 35 g (2002, 2003) satellite platform transmitting terminal (PTT) in the right abdominal air sac (Korschgen et al. 1996, Hupp et al. 2006b). We deployed 15, 20, and 18 PTTs in 1999, 2002, and 2003, respectively. All females were marked with a colored plastic leg band with a unique alphanumeric code.

Most PTTs were programmed to transmit once each minute for eight hours in each 30-hour interval beginning in early April, before birds returned to the YKD from winter sites. However, three PTTs were programmed to transmit six hours during each 72-hour

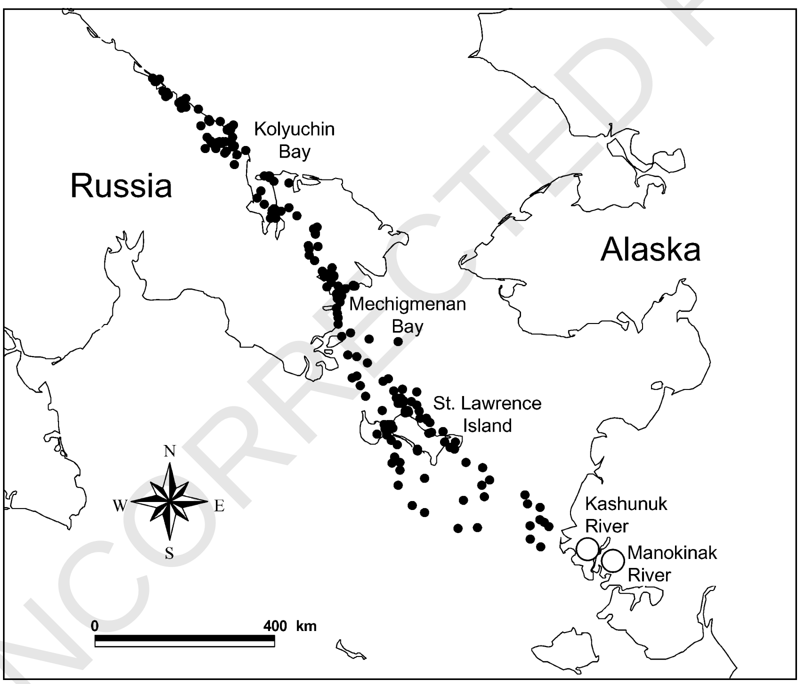

Fig. 1. Satellite transmitter locations of 12 emperor geese as they migrated from the Yukon-Kuskokwim Delta, Alaska to moulting areas on St. Lawrence Island and the Chukotka Peninsula, Russia, June 2000, 2003 and 2004. Each darkened point represents a single satellite transmitter location of an individual bird as it migrated. Open circles are capture sites at the Manokinak and Kashunuk rivers on the Yukon-Kuskokwim Delta in western Alaska.

interval throughout their life. We received data through the Argos Data Collection and Location System. Location quality (LQ) was assigned following Harris et al. (1990). PTTs also transmitted data on body temperature and battery potential, providing us with an indication of whether birds were alive and the status of the battery. Projected operating life of PTTs was approximately 12 months.

We determined reproductive status of females with PTTs when they returned to the YKD in the spring after they were marked. We used a hand-held frequency scanner and intensively searched areas where we had received repeated locations from a PTT to locate nesting females. We confirmed that discovered nests were those of radioed birds by sighting the PTT antenna or by reading the code on the plastic leg band. We rarely obtained visual observations of females not discovered on nests. Their reproductive status was based on movements during the nesting season. We tracked movements of geese until their PTTs failed in mid to late summer.

Aerial surveys

We (EES and AVK) performed aerial surveys in Chukotka on 24–29 July 2002, a period when geese were likely moulting remiges. The survey route encompassed coastal wetlands of northern Chukotka, and coastal and interior wetlands near Anadyr Bay and Anadyr River of south Chukotka. The surveys were conducted from an AN-3 aircraft flown at 50–70 m above ground level at a speed of 130–150 km/h. Two observers in the rear of the aircraft, and a navigator-observer in the forward part of the aircraft recorded sightings of emperor geese and other waterfowl within 200 m of either side of the aircraft. Identification of the 200-m boundary was facilitated by marks on the lower wing of the aircraft. Aircraft location and time were recorded every two minutes via a Global Positioning System (GPS) receiver. Observations of emperor geese were recorded onto tape recorders along with time of sightings so that locations of flocks could be determined from the GPS record.

Data analysis

We analyzed PTT data via a computer program (Douglas 2006) that enabled us to remove unlikely locations based on the rate of movement, and distance and angle between locations. We first used a robust set of criteria that resulted in retention of a location if it was ≤30 km from the previous or subsequent positions, and if the rate of movement between adjacent locations was ≤80 km/h. This retained locations of birds in flight and yielded information on the route geese followed between the YKD and moulting areas. We scrutinized those locations and considered that birds were in flight if they moved >50 km in one direction during a six or eight hour transmission cycle. We then reanalyzed the data with more stringent criteria to retain locations that were ≤5 km from previous or subsequent positions, and for which rate of movement was ≤10 km/h. We used those locations to identify areas used by geese after they had reached moulting areas and were more sedentary. From that data set we selected the location that had the highest quality (Harris et al. 1990) within each six or eight hour transmission period to represent an individual's daily position. We only retained poor quality locations (LQ = 0, A, or B) from moulting areas if they occurred ≤1 km from a high quality location (LQ = 1, 2, or 3) for that same individual.

The aerial survey route was divided into 55 segments that averaged approximately 60 km in length. The number of emperor geese observed in each segment was tallied and their location represented by the midpoint of the segment as plotted in ArcMap (ESRI 2004).

Results

Satellite telemetry

Of the 53 females that were marked with PTTs, 34 returned to the YKD and had functional radios throughout the nesting season. We found 16 of those females on nests, all of which hatched young. Most of the females that successfully nested remained on the YKD following hatch. However, one female departed the YKD on 25 June, 12 d after hatching five eggs. Sixteen females were not found on nests and they departed the YKD from 10 d prior until two days after median hatch date of other radioed birds, indicating they likely either did not nest or nested unsuccessfully, although some could have lost broods soon after hatch. Median date of departure for those individuals was 9 June (range 3–15 June), 21–38 d after their arrival on the nesting area (median = 31 d). We are uncertain of the reproductive status of two females that were never visually sighted but that remained on the YKD after hatch. Based on high quality locations, one of those individuals moved 16 km during the period when other females were incubating, suggesting she likely did not successfully nest. We believe the other female probably did nest as she moved <2 km during the nesting season, similar to the distance moved by females observed on nests.

We observed the largest number of moult migrants in 2003 (10 of 13 PTTs) with smaller numbers in 2000 (2 of 8 PTTs), and 2004 (5 of 15 PTTs). Sixteen females migrated to the north coast of the Chukotka Peninsula in Russia, including the female that successfully hatched young. One female migrated to St. Lawrence Island. We received 191 locations from 12 females as they were in flight (Fig. 1). Following departure from the YKD, emperor geese transited the Bering Sea to St. Lawrence Island and made landfall in Russia near Mechigmenan Bay. Migration was rapid and among the 14 geese whose PTTs transmitted daily, first detection in Russia occurred either one or two days after last detection on the YKD. Many birds may have made the approximately 850 km transoceanic migration between Alaska and Russia without stopping. However, six of the 16 females that migrated to Russia were detected for brief periods (<4 h) on St. Lawrence Island, the only potential stopover site during their migration. Following arrival in Russia, emperor geese continued with a 200–700 km overland migration to Kolyuchin Bay and other sites on the north coast of the Chukotka Peninsula. Total migration distance between YKD nesting areas and Russian moulting areas was 1,000–1,500 km.

In June we received 151 daily locations from 16 PTTs after geese had settled in Russia (Fig. 2). June locations were probably obtained when geese were still capable of flight. They were more widely distributed

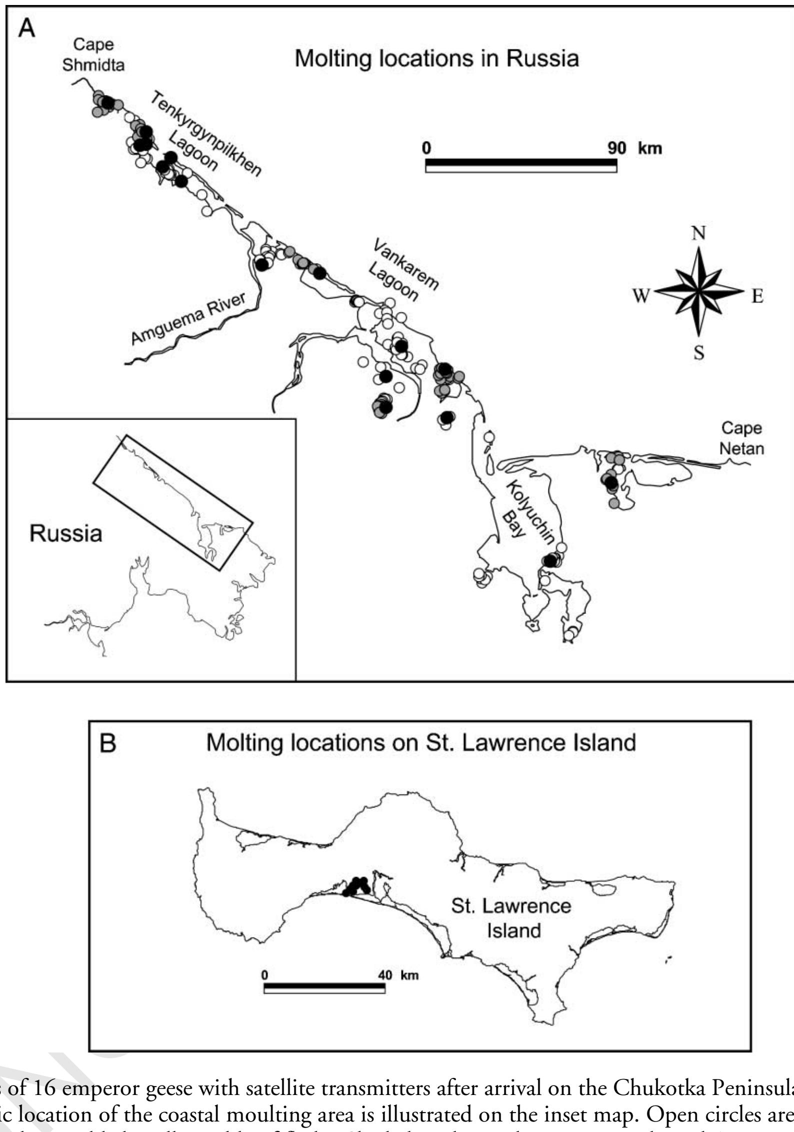

Fig. 2. (A) Locations of 16 emperor geese with satellite transmitters after arrival on the Chukotka Peninsula, Russia, 2000, 2003 and 2004. Geographic location of the coastal moulting area is illustrated on the inset map. Open circles are locations of emperor geese in June when birds were likely still capable of flight. Shaded circles are locations in July and August when geese were likely flightless. Blackened circles are final locations for PTTs that failed prior to departure from Russia, or location on August 1 for two females that departed Russia prior to transmitter failure. (B) Locations of a single female emperor goose that moulted on St. Lawrence Island, Alaska, June and July, 2003.

than the July and August locations, and 60% were in inland habitats >2 km from the coast. Seven of the PTTs failed in June whereas nine continued to transmit in July and August when geese were likely flightless. During the flightless period eight of the nine emperor geese with active PTTs in Russia used coastal lagoons between Cape Shmidta and Cape Netan (Fig. 2). Final locations for seven of the geese were in or near Tenkyrgynpilkhen Lagoon. Most (75%) of the 90 locations obtained for emperor geese in Chukotka in July and August were ≤ 2 km from the coast, suggesting greater use of coastal habitats during remigal moult. The lone female that moulted on St. Lawrence Island, did so on the south coast (Fig. 2).

PTTs of 15 of the 17 moult migrants failed before geese departed their moulting areas. Body temperature data indicated all geese were alive at the time of battery failure. One individual departed Russia on 29 August and another on 11 September, 70–71 d after first detection in Chukotka. One bird remained on St. Lawrence Island for 4–7 d before migrating to an autumn staging area on the Alaska Peninsula. The final location for the other individual was over open ocean 250 km east of the Pribilof Islands, Alaska where it may have been en route to staging areas. Neither goose was detected on the YKD after departure from Russia.

Aerial surveys

We flew approximately 3,200 km of aerial surveys in Chukotka and observed a total of 21,150 emperor geese that were in adult plumage. We observed only 56 broods. Most (94%) emperor geese were observed on the north coast of Chukotka, with the largest concentration (8,900 birds) in western Tenkyrgynpilkhen Lagoon (Fig. 3). Flocks in that area were in salt marshes that occurred in a broad delta where several rivers entered the lagoon. In south Chukotka, most emperor geese were observed along the southern coast of Anadyr Bay and small flocks were seen in Kresta Bay.

Discussion

Our PTT data indicate that most adult emperor geese that do not reproduce depart the YKD, primarily for moulting sites in Russia. A small percentage of pairs that successfully nest may also depart the YKD. Gosling survival is lowest within five days of hatch (Schmutz et al. 2001), and some geese that successfully nest may depart the YKD if they experience early loss of broods. We observed the largest number of moult migrants in 2003. Indices of arctic fox *Alopex lagopus* abundance on the YKD suggested the fox population in 2003 was at

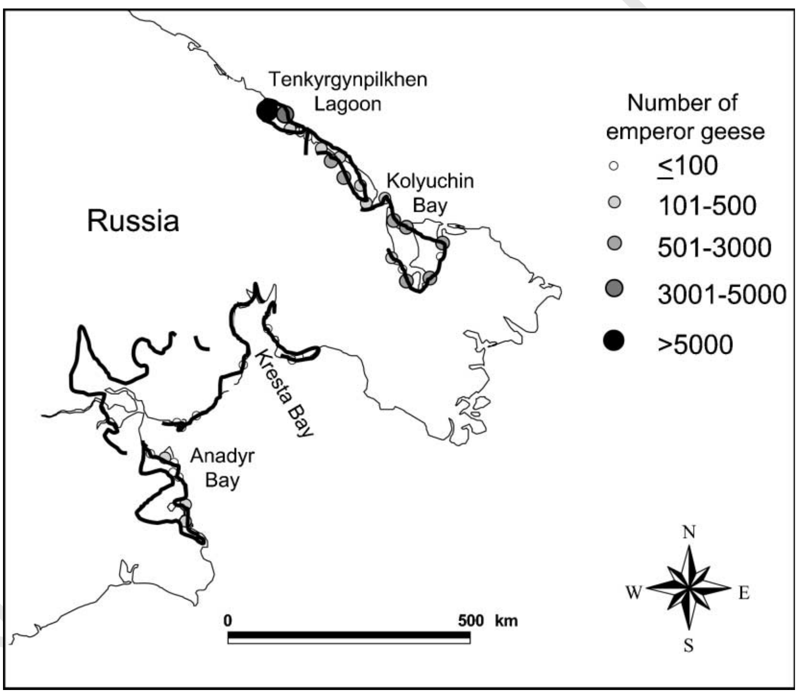

Fig. 3. Number and distribution of emperor geese observed during aerial surveys in Chukotka, Russia, July 2002. Survey routes are indicated by dark lines. Numbers of geese observed were tallied by survey segment and location plotted at the midpoint of a segment.

its second highest level for the period from 1988–2004 (J. B. Fischer unpubl. data). Consequently, nest survival was poor (Fischer et al. 2003) and nests of most marked females were likely destroyed before they could be discovered. Other studies have also noted that variation in reproductive success can result in annual differences in the number of geese that undertake moult migrations (Abraham 1980, Davis et al. 1985, Reed et al. 2003).

We estimated the number of nonproductive adult emperor geese that could potentially migrate to moulting areas based on a 10-year average (1995–2004) of 57,200 nesting individuals (females and their mates) on the YKD (Fischer et al. 2004), a nest failure rate of 0.1 (Petersen 1992), and nesting propensity of 0.8 (J. A. Schmutz unpubl.data). Even in a year with 90% nest survival, approximately 20,000 reproductive-age emperor geese on the YKD may be failed nesters or non-breeders. This represents 28% of the average annual adult population. Petersen (1992) observed nest survival as low as 0.1%, thus the number of failed breeders could be much higher in years of poor reproductive success. Depending on reproductive success during the previous two years, geese that have not yet reached breeding age could increase the number of moult migrants substantially. There is little evidence that emperor geese breed before three years of age (Schmutz 2000), and birds believed to be yearlings have been observed to depart the YKD prior to moult (Blurton Jones 1972, Eisenhauer and Kirkpatrick 1977). The number of geese that are not of breeding age could exceed 49,000 based on annual estimates of number of emperor goose nests on the YKD from 1995–2004 in Fischer et al. (2004), annual apparent nest survival of 39–87% during that period on the Kashunuk River (C. R. Ely unpubl. data), eggs hatched/nest (4.4) in Petersen (1992), gosling survival (0.53) in Schmutz et al. (2001), and yearling (0.62) and adult annual survival (0.85) in Schmutz et al. (1997). Therefore nearly 70,000 emperor geese that are either failed nesters, non-breeders, or birds that have not reached breeding age may depart the YKD for moulting areas on St. Lawrence Island or Russia. We acknowledge that moulting location for birds <3 years of age is unknown. However in other species of geese moulting areas of juveniles coincides with that of adults that failed to successfully reproduce (Salomonsen 1968, Abraham 1980, Abraham et al. 1999).

Our estimates of nonproductive geese combined with the estimate for nesting individuals on the YKD (Fischer et al. 2004) exceed recent spring population indices for emperor geese (U. S. Fish and Wildlife Service 2005). This could reflect uncertainty in estimates of the size of the nesting population on the YKD, or errors in the nesting and survival parameters used to compute the numbers of nonproductive birds in the population. Also, spring surveys may not account for all components of the population. Regardless, our telemetry data, combined with recent estimates of the nesting population and reproductive success on the YKD, and aerial surveys in Russia suggest that a large proportion of the emperor goose population in western Alaska may use areas other than the YKD during moult.

Sixteen of the 17 emperor geese that departed the YKD moulted in Russia, primarily at coastal lagoons west of Kolyuchin Bay. This same region contained the largest concentrations of emperor geese observed during aerial surveys in 2002. Only 0.2% of the emperor geese observed in Chukotka were goslings, indicating the birds were likely not from a local breeding population. Nesting success on the YKD was high in 2002 (Bowman et al. 2002), and the number of emperor geese observed during aerial surveys in Chukotka was comparable to our estimate of 20,000 failed and non-breeders of adult age that may depart Alaska in such years.

However, the number of geese observed in Russia was substantially lower than expected had the approximately 40,000 emperor geese that we estimate were not of reproductive age in that year also departed the YKD to moult in Chukotka. The aerial survey count was likely conservative because geese were only tallied if they were within 200 m of the aircraft, there was no correction factor applied for undetected birds, and the survey estimates were not expanded to unsurveyed areas. Thus more emperor geese could have been in Chukotka, but not counted during the survey.

The aerial surveys of 2002 were the most comprehensive evaluation of numbers and distribution of moulting emperor geese in Chukotka yet conducted. Hodges and Eldridge (2001) estimated that 2,900 emperor geese used the north coast of Chukotka in 1993. However their June survey was intended to count breeding waterfowl and may have occurred before most emperor geese had arrived at Russian moulting sites. Surveys of Eldridge et al. (1993) did not include areas west of Kolyuchin Bay where most emperor geese occurred. Large numbers of moulting emperor geese were reported to use coastal lagoons on the north coast of Chukotka by Kistchinski (1971, 1976) and Portenko (1972), and moulting flocks have been observed at Kolyuchin Bay (A. V. Kondratyev pers. obs.). Although, it is not possible to estimate total numbers of moulting birds from these observations, they are consistent with an influx of moult migrant emperor geese from Alaska. Arrival of emperor geese at Mechigmenan and Kolyuchin bays in June has been observed by local people in Chukotka for decades (E. E. Syroechkovskiy unpubl. data). Emperor geese have been observed to arrive at Kolyuchin Bay from the east and south (Kretchmar et al. 1978) similar to the routes taken by birds with PTTs.

Emperor geese did not use other important Beringian moulting or breeding areas such as the coastal region bewteen the Kolyma and Yana rivers west of Cape Shmidta (Hodges and Eldridge 2001), Wrangel Island (Syroechkovskiy and Litvin 1986, Ward et al.1993), or the North Slope of Alaska (King and Hodges 1979, Derksen et al. 1979) that are used by Pacific black brant *Branta bernicla nigricans*, lesser snow geese *Chen caerulescens caerulescens*, white-fronted geese *Anser albifrons*, or Canada geese *Branta canadensis*. By molting on the north coast of Chukotka, emperor geese may avoid large breeding and moulting populations of other species of geese that occur elsewhere. However, we did observe approximately 8000 white-fronted geese and 4000 Pacific black brant on the north coast of Chukotka during aerial surveys, indicating the region is used by components of those species' populations.

The features that make the north coast of Chukotka attractive to moulting emperor geese may not be widely available elsewhere in Chukotka or on St. Lawrence Island. The lagoons and estuaries of the north coast provide large areas of open water where moulting birds can escape mammalian predators (Salomonsen 1968, Derksen et al. 1982, Hohman et al. 1992), and they contain salt marshes where forage species such as *Dupontia fischeri* and *Carex subspathacea* are available (Kistchinski 1971). Based on examination of the Circumpolar Arctic Vegetation Map (CAVM Team 2003), most (78%) of the coastal lagoons in Chukotka occur on the north shore in the region used by moulting emperor geese. Lagoon systems of comparable size do not exist on the south coast of Chukotka or on St. Lawrence Island (CAVM Team 2003). Importantly, the north coast of Chukotka is sparsely settled and human disturbance, which can cause moulting geese to shift areas of use (Sterling and Dzubin 1967), is minimal. Other coastal regions of Chukotka are more densely populated and may be less attractive to moulting emperor geese (E. E. Syroechkovskiy pers. obs.). St. Lawrence Island was formerly used by 10,000–20,000 moulting emperor geese and was once believed to be the species' primary moulting area (Fay 1961). However, only one of 17 radiomarked emperor geese used St. Lawrence Island, and aerial surveys from 1984–1988 indicated only 2,800–3,800 emperor geese moulted there (U. S. Fish and Wildlife Service unpubl. data). We know little about factors that might have displaced emperor geese from St. Lawrence Island. However, Fay (1961) noted that native subsistence harvest of emperor geese on St. Lawrence Island was common. That practice continues although there are no published estimates of native harvest.

Costal areas of north Chukotka are among the more important anserine moulting habitats in Beringia. Events that affect survival of emperor geese on Russian moulting areas may have consequences for population trends in Alaska. Because anthropogenic disturbance on moulting areas can be detrimental to geese (Stirling and Dzubin 1967, Derksen et al. 1982, Miller et al. 1994), the coastal region between Cape Shmidta and Cape Netan needs protection to conserve habitats used by this internationally important goose population. Coastal lagoons in that region are not currently protected as state refuges. Though isolated, coastal Chukotka may see greater human activity in future years as a result of nearby mineral development, increased commercial fishing, and if marine shipping in the region increases as polar ice recedes due to global change (Arctic Climate Impact Assessment 2004). Additional aerial surveys are needed to obtain a more complete estimate of emperor geese that moult in Chukotka and to delineate areas of use. Migration chronology and summer distribution of emperor geese that have not reached reproductive age should be evaluated.

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References

Abraham, K. F. 1980. Moult migration of lesser snow geese. 1980. – Wildfowl 31: 89–93.

Abraham, K. F., Leafloor, J. O. and Rusch, D. H. 1999. Molt migrant Canada geese in northern Ontario and western James Bay. – J. Wildl. Manage. 63: 649–655.

Arctic Climate Impact Assessment. 2004. Impacts of a warming Arctic: Arctic climate impact assessment. – Cambridge University Press, Cambridge.

Blurton Jones, N. G. 1972. Moult migration of emperor geese. – Wildfowl 23: 92–93.

Bollinger, K. S. and Derksen, D. V. 1996. Demographic characteristics of moulting black brant near Teshekpuk Lake, Alaska. – J. Field Ornith. 67: 141–158.

Bowman, T., Fischer, J., Stehn, R. and Walters, G. 2002. Population size and production of geese and eiders nesting on the Yukon-Kuskokwim Delta, Alaska in 2002. – U.S. Fish and Wildlife Service, Anchorage.

CAVM Team. 2003. Circumpolar arctic vegetation map. Conservation of Arctic flora and fauna (CAFF) map no.

1. – U.S. Fish and Wildlife Service, Anchorage. http://www.geobotany.uaf.edu/cavm/

Davis, R. A.., Jones, R. N., MacInnes, C. D. and Pakulak, A.. J. 1985. Molt migration of large Canada geese on the west coast of Hudson Bay. – Wilson Bull. 97: 296–305.

Derksen, D. V., Eldridge, W. D. and Weller, M. W. 1979. Distributional ecology of geese molting near Teshekpuk Lake, National Petroleum Reserve-Alaska. – In: Jarvis, R. L. and Bartonek, J. C. (eds). Management and biology of Pacific Flyway geese. Oregon State University Bookstores, Inc., Corvallis, pp. 189–207.

Derksen, D. V., Eldridge, W. D. and Weller, M. W. 1982. Habitat ecology of Pacific black brant and other geese molting near Teshekpuk Lake, Alaska. – Wildfowl 33: 39–57.

Douglas, D. 2006. The Douglas Argos-filter program. – U.S. Geological Survey, Anchorage. http://alaska.usgs.gov/science/biology/spatial/douglas.html

Eldridge, W. D., Hodges, J. I., Syroechkovskiy, E. V. and Kretchmar, E. V. 1993. The Russian-American aerial waterfowl surveys in the north-eastern Asia in 1992. – Russian J. Ornithol. 2: 457–460.

Eisenhauer, D. I. and Kirkpatrick, C. M. 1977. Ecology of the emperor goose in Alaska. – Wildl. Monogr. 57: 1–62.

ESRI. 2004. ArcGIS 9: Using ArcMap. – ESRI, Redlands, California, U.S.A.

Fay, F. H. 1961. The distribution of waterfowl to St. Lawrence Island, Alaska. – Ann. Rep. Wildfowl Trust 12: 70–80.

Fischer, J. B., Bowman, T. D., Stehn, R. A. and Walters, G. 2003. Population size and production of geese and eiders nesting on the Yukon-Kuskokwim Delta, Alaska in 2003. – U. S. Fish and Wildlife Service, Anchorage.

Fischer, J. B., Stehn, R. A., Bowman, T. D. and Walters, G. 2004. Nest populations and potential production of geese and spectacled eiders on the Yukon-Kuskokwim Delta, Alaska, 2004. – U. S. Fish and Wildlife Service, Anchorage.

Fox, A. D. and Kahlert, J. 2000. Do moulting greylag geese *Anser anser* forage in proximity to water in response to food availability and/or quality? – Bird Study 47: 266–274.

Harris, R. B., Fancy, S. G., Douglas, D. C., Garner, G. W., Amstrup, S. C., McCabe, T. R. and Pank, L. F. 1990. Tracking wildlife by satellite: current systems and performance. – U. S. Fish and Wildlife Service Technical Report 30, Washington, D.C.

Hodges, J. I. and Eldridge, W. D. 2001. Aerial surveys of eiders and other waterbirds on the eastern Arctic coast of Russia. – Wildfowl 52: 127–142.

Hohman, W. L, Ankney, C. D. and Gordon, D. H. 1992. Ecology and management of postbreeding waterfowl. – In: Batt, B. D. J., Afton, A. D., Anderson, M. G., Ankney, C. D., Johnson, D. H., Kadlec, J. A. and Krapu, G. L. (eds). Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis, pp. 128–189.

Hupp, J. W., Schmutz, J. A.and and Ely, C. R. 2006a. The prelaying interval of emperor geese on the Yukon-Kuskokwim Delta, Alaska. – Condor 108: 912–924.

Hupp, J. W., Pearce, J. M., Mulcahy, D. M. and Miller, D. A. 2006b. Effects of abdominally implanted radio transmitters with percutaneous antennas on migration, reproduction, and survival of Canada geese. – J. Wildl. Manage. 70: 812–822.

Kear, J. 2005. Ducks, geese, and swans. – Oxford University Press, Oxford.

King, J. G. and Hodges, J. I. 1979. A preliminary analysis of goose banding on Alaska's Arctic slope. – In: Jarvis, J. L. and Bartonek, J. C. (eds). Management and biology of Pacific Flyway geese. Oregon State University Bookstores, Inc., Corvallis, pp. 176–188.

Kistchinski, A. A. 1971. Biological notes on the emperor goose in north-east Siberia. – Ann. Rep. Wildfowl Trust 22: 29–34.

Kistchinski, A. A. 1976. Waterfowl populations on the Chukotsk Peninsula. – Bulletin of MOIP, Biology Division 81: 40–50.

Kretchmar, A.V., Andreev, A. V. and Kondratyev, A. Y. 1978. Ecology and distribution of birds in the North East of USSR. – Nauka Press, Moscow.

Korschgen, C. E., Kenow, K. P., Gendron-Fitzpatrick, A., Green, W. L. and Dein, F. J. 1996. Implanting intra-abdominal radiotransmitters with external whip antennas in ducks. – J. Wildl. Manage. 60: 132–137.

Lawrence, J. S., Perkins, G. A., Thornburg, D. D., Williason, R. A. and Klimstra., W. D. 1998. Molt migration of giant Canada geese from west-central Illinois. – In: Rusch, D. H.., Samuel, M. D., Humburg, D. D. and Sullivan, B. D. (eds). Biology and management of Canada geese. Proceedings of the international Canada goose symposium. Milwaukee, pp. 105–111.

Miller, M. W. 1994. Route selection to minimize helicopter disturbance of molting Pacific black brant-a simulation. – Arctic 47: 341–349.

Miller, M. W., Jensen, K. C., Grant, W. E. and Weller, M. W. 1994. A simulation model of helicopter disturbance of molting Pacific black brant. – Ecol. Modeling 73: 293–309.

Owen, M. and Ogilvie, M. 1979. Wing molt and weights of barnacle geese in Spitsbergen. – Condor 81: 42–52.

Petersen, M. R. 1992. Reproductive ecology of emperor geese: annual and individual variation in nesting. – Condor 94: 383–397.

Petersen, M. R., Schmutz, J. A. and Rockwell, R. F. 1994. Emperor goose (*Chen canagica*). – In: Poole, A. and Gill, F. (eds). The birds of North America, no. 97. The Academy of Natural Sciences, Philadelphia. The American Ornithologists Union, Washington, D.C.

Portenko, L. A. 1972. The birds of the Chukotsk Peninsula and Wrangel Island. – Nauka Press, St. Petersburg.

Reed, E. T., Bety, J., Mainguy, J., Gauthier, G. and Giroux, J.-F. 2003. Molt migration in relation to breeding success in greater snow geese. – Arctic 56: 76–81.

Salomonsen, F. 1968. The moult migration. – Wildfowl 19: 5–24.

Schmutz, J. A. 2000. Age-specific breeding in emperor geese. – Wilson Bull. 112: 261–263.

Schmutz, J. A. and Kondratyev, A. V. 1995. Evidence of emperor geese breeding in Russia and staging in Alaska. – Auk 112: 1037–1038.

Schmutz, J. A., Rockwell, R. F. and Petersen, M. R. 1997. Relative effects of survival and reproduction on the population dynamics of emperor geese. – J. Wildl. Manage. 61: 191–201.

Schmutz, J. A., Manly, B. F. and Dau, C. P. 2001. Effects of gull predation and weather on survival of emperor goose goslings. – J. Wildl. Manage. 65: 248–257.

Sterling, T. and Dzubin, A. 1967. Canada goose molt migrations to the Northwest Territories. – N. Am. Wildl. Conf. 23: 355–373.

Stirling and Dzubin 1967. **Please provide further details**

Syroechkovskiy, Y. V. and Litvin, K. Y. 1986. Investigation of the migration of the snow geese of Wrangel Island by the method of individual marking. – In: Sokolov, V. Y. and Dobrinina, I. N. (eds). The ringing and marking of birds in the USSR, 1979–1982. – Nauka Press, Moscow, pp. 5–20.

U. S. Fish and Wildlife Service. 2005. Waterfowl population status, 2005. – U. S. Department of the Interior, Washington, D.C. http://migratorybirds.fws.gov/reports/status05/final_status_05.pdf

Ward, D. H., Derksen, D. V., Kharitonov, S. P., Stishov, M. and Baranyuk, V. V. 1993. Status of Pacific black brant *Branta bernicla nigricans* on Wrangel Island, Russian Federation. – Wildfowl 44: 39–48.

Zicus, M. C. 1981. Molt migration of Canada geese from Crex Meadows, Wisconsin. – J. Wildl. Manage. 45: 54–63.